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FINAL REPORT for JOVE Project
Summer 1990, 1991

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During summer 1990, A. Odell (Northern Arizona University; NAU) and T. Snow (University of Colorado; CU) worked on a preliminary version of a catalog of ultraviolet (UV) spectral lines which show effects of absorption by stellar winds. During summer, 1991 the catalog was improved and expanded by Odell and H. Lamers (SRON Laboratory for Space Research, Utrecht, Holland). The International Ultraviolet Explorer (IUE) satellite is ideally suited to provide high resolution (0.05A) UV spectra of bright stars, and in fact an archive of several thousand such spectra already exist.

Atoms moving away from a star's surface absorb or emit light at the particular wavelength appropriate to the type of atom, but shifted to the red or blue depending on the velocity of the atom relative to the star's surface and to the earth (Doppler shift). The profile of the spectral line depends on the number of atoms of a certain type and the velocity; therefore in principal, the rate of mass loss can be found. Practical problems arise from a poor understanding of the ionization of atoms in the wind and the fact that the strongest lines completely absorb all of the light from the star before all atoms have had a chance to absorb (the lines are saturated).

The theory and problems can be best understood by an example. Carbon atoms produce lines at 1550A (thrice ionized), 1175A (twice ionized), 1334A (once ionized), and 1656A (neutral). In the spectrum of a B0 (surface temperature 30,000K) supergiant star, the 1550A and 1175A lines are so strong that all of the light from the star is absorbed by the wind atoms; this indicates only a lower limit on the number of absorbers. The 1334A and 1656A lines are very weak, indicating essentially no absorbers. To find the amount of carbon in the wind, the true number of absorbers of a certain ionization (impossible for any of these species) must be known, and the fraction of carbon atoms in each ionization state (very uncertain). The ionization of the wind atoms comes about not from photoionization by stellar UV photons, but from another ill-understood source, probably shock-generated and/or other x-rays. Thus for the carbon ions which have high fractional abundance (so that uncertainty is not so important) only lower limits to the abundance can be derived, while the ions with better-determined abundances represent a very small and uncertain fraction of all carbon.

The purpose of the JOVE project between NAU and CU during the summers of 1990 and 1991 is to produce a homogeneous set of a large number of UV stellar spectra of lines which indicate mass loss for a variety of different kinds of stars. This catalog will be useful in several respects, such as the following:

--derivation of wind parameters and how they depend on such things as stellar temperature, size, and rotation rate, to provide better understanding of how and why these stars lose mass at all.

--a star's mass and age are the two primary things which determine what the star looks like. Thus if a star loses a substantial part of its mass during its lifetime, its behavior will be radically altered from what is expected with little or no mass loss.

--guidance for observations of more distant stars with Hubble Space Telescope to determine mass-loss rates of stars in nearby galaxies, which have substantially different abundances of heavy elements from those in nearby stars. Eventually, this can lead to better understanding of stellar evolution in these other galaxies.

During the summer of 1990, Odell and Snow produced a first-draft catalog containing about 40 spectra of 25 stars, including eight lines for each spectrum. This effort was expanded in summer 1991 by Odell and Lamers to better represent the data, and to include about 60 stars with two or more spectra each.

During the process, it was realized that no one had ever systematically displayed and described the UV spectra of cooler supergiant stars. Because of this, considerable effort was put into a short catalog containing 12 stars, but with the entire spectrum represented and described.

A graduate student (D. Lindholm of CU) has been given the task of continuing work on the main catalog of line profiles during the 1991-2 academic year. He will extract, reduce, and produce plots of an additional approximately 140 stars, to be chosen by Lamers and Odell. These stars will be chosen to specifically fill in gaps in the catalog so that a smooth variation of stellar parameters is represented. This work should be done by summer 1992, so that the entire catalog can be assembled, printed, and made available to the astronomical community.